518 Rec'd PCT/PTO 06 AUG 2001

FORM PTO-1390 (REV. 5-93) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER **10191/1896**
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/890831

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED:
PCT/DE99/03468	**30 October 1999 (30.10.99)**	**04 February 1999 (04.02.99)**

TITLE OF INVENTION
ROTARY ACTUATOR AND ROTARY SWITCH

APPLICANT(S) FOR DO/EO/US
Eckart HETTLAGE

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information.

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have. been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)) (unsigned).
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1 98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
14. ☒ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: International Search Report (translated), Preliminary Examination Report and PCT/RO/101.

EXPRESS MAIL NO.: EL244504400

JC05 Rec'd PCT/PTO 06 AUG 2001

U.S. APPLICATION NO. (if known, see 37 C.F.R.1.5) 09/890831	INTERNATIONAL APPLICATION NO. PCT/DE99/03468	ATTORNEY'S DOCKET NUMBER 10191/1896

17. ☒ The following fees are submitted:

Basic National Fee (37 CFR 1.492(a)(1)-(5)):

Search Report has been prepared by the EUROPEAN PATENT OFFICE or JPO . . . . q$860.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) $690.00

No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) $710.00

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO $1,000.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100.00

				CALCULATIONS	PTO USE ONLY
ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 860	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$	
Claims	Number Filed	Number Extra	Rate		
Total Claims	12 - 20 =	0	X $18.00	$ 0	
Independent Claims	2 - 3 =	0	X $80.00	$ 0	
Multiple dependent claim(s) (if applicable)			+ $270.00	$	
TOTAL OF ABOVE CALCULATIONS =				$ 860	
Reduction by ½ for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				$	
SUBTOTAL =				$ 860	
Processing fee of $130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ 860	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$	
TOTAL FEES ENCLOSED =				$ 860	
				Amount to be: refunded	$
				charged	$

a. ☐ A check in the amount of $________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of **$860.00** to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

By: [signature] (Reg. No. 41,172)

[signature]
SIGNATURE

Richard L. Mayer, Reg. No. 22,490
NAME

8/6/01
DATE

SEND ALL CORRESPONDENCE TO:
Kenyon & Kenyon
One Broadway
New York, New York 10004

Customer No. 26646

10/911896

EXPRESS MAIL CERTIFICATE

"EXPRESS MAIL" MAILING LABEL NUMBER EL244504400

DATE OF DEPOSIT 8/6/01

TYPE OF DOCUMENT Patent App (Nat'l Phase)

Hettlage'S Rotary Actuater and Rotary Switch.

SERIAL NO. To be Assigned FILING DATE Herewith

I HEREBY CERTIFY THAT THIS PAPER OR FEE IS BEING DEPOSITED WITH THE UNITED STATES POSTAL SERVICE "EXPRESS MAIL POST OFFICE TO ADDRESSEE" SERVICE UNDER 37 CFR 1.10 ON THE DATE INDICATED ABOVE, BY BEING HANDED TO A POSTAL CLERK OR BY BEING PLACED IN THE EXPRESS MAIL BOX BEFORE THE POSTED DATE OF THE LAST PICK UP, AND IS ADDRESSED TO THE ASSISTANT COMMISSIONER FOR PATENTS, WASHINGTON, D.C. 20231.

DAVID Postolski

(PRINTED NAME OF PERSON MAILING PAPER OR FEE)

(SIGNATURE OF PERSON MAILING PAPER OR FEE)

09/890831

JC05 Rec'd PCT/PTO 06 AUG 2001

[10191/1896]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s)	:	Eckart HETTLAGE
Serial No.	:	To Be Assigned
Filed	:	Herewith
For	:	ROTARY ACTUATOR AND ROTARY SWITCH
Art Unit	:	To Be Assigned
Examiner	:	To Be Assigned

Assistant Commissioner
for Patents
Washington, D.C. 20231
Box Patent Application

PRELIMINARY AMENDMENT AND 37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT

SIR:

Please amend the above-identified application before examination, as set forth below.

IN THE SPECIFICATION AND ABSTRACT:

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification (including the Abstract, but without claims) accompanies this response. It is respectfully requested that the Substitute Specification (including Abstract) be entered to replace the Specification of record.

IN THE CLAIMS:

On the first page of the claims, first line, change "What is claimed is:" to: --What Is Claimed Is:--.

Please cancel original claims 1 to 13, without prejudice, and cancel substitute claims 1-12, without prejudice, in the underlying PCT Application No. PCT/DE99/03468.

EL244504400

Please add the following new claims:

13. (New) A rotary actuator, comprising:

a permanently magnetized rotor;

a plurality of stator windings surrounding the permanently magnetized rotor in a rim-like fashion and for generating a magnetic field, the stator windings placing the permanently magnetized rotor in one of a first plurality of positions;

an arrangement for exerting a corrective torque on the permanently magnetized rotor, the arrangement for exerting the corrective torque, in a currentless state of the stator windings, placing the permanently magnetized rotor in a target position of a second plurality of positions, each position of the first plurality of positions having assigned thereto a corresponding one of the second plurality of positions as the target position; and

a network having n inputs and m outputs, n being a number of the first plurality of positions and m being a number of the stator windings, wherein:

each one of the stator windings is connected to one of the m outputs, and

the network distributes to the stator windings a current applied at one of the n inputs in order to set one of the first plurality of positions that is assigned to a respective one of the n inputs.

14. (New) The rotary actuator according to claim 13, wherein:

the permanently magnetized rotor includes a magnet that is aligned so as to be perpendicular to a rotational axis.

15. (New) The rotary actuator according to claim 13, wherein:

the stator windings are arranged so as to be unpaired.

16. (New) The rotary actuator according to claim 13, wherein:

the stator windings are uniformly distributed around a rotational axis in a circumferential direction.

17. (New) The rotary actuator according to claim 13, further comprising:

a ring core surrounding the permanently magnetized rotor and on which the stator windings are arranged.

18. (New) The rotary actuator according to claim 13, wherein:

the number m of the stator windings is smaller than the number n of the first plurality of positions.

19. (New) The rotary actuator according to claim 13, wherein:

the arrangement for exerting the corrective torque includes a plurality of permanent magnets.

20. (New) The rotary actuator according to claim 13, wherein:

a resistance of all n inputs is the same.

21. (New) The rotary actuator according to claim 13, wherein:

the stator windings include three stator windings, and

the plurality of first positions includes four first positions.

22. (New) The rotary actuator according to claim 13, wherein:

adjoining target positions have an angular distance of 45°.

23. (New) A rotary switch, comprising:

a rotary actuator that includes:

a permanently magnetized rotor;

a plurality of stator windings surrounding the permanently magnetized rotor in a rim-like fashion and for generating a magnetic field, the stator windings placing the permanently magnetized rotor in one of a first plurality of positions;

an arrangement for exerting a corrective torque on the permanently magnetized rotor, the arrangement for exerting the corrective torque, in a currentless state of the stator windings, placing the permanently magnetized rotor in a target position of a second

plurality of positions, each position of the first plurality of positions having assigned thereto a corresponding one of the second plurality of positions as the target position; and

a network having n inputs and m outputs, n being a number of the first plurality of positions and m being a number of the stator windings, wherein:

each one of the stator windings is connected to one of the m outputs, and

the network distributes to the stator windings a current applied at one of the n inputs in order to set one of the first plurality of positions that is assigned to a respective one of the n inputs.

24. (New) The rotary switch according to claim 13, wherein:

the rotary switch is an "R"-type waveguide switch.

Remarks

This Preliminary Amendment cancels original claims 1 to 13, without prejudice, and cancels substitute claims 1-12, without prejudice, in the underlying PCT Application No. PCT/DE99/03468. The Preliminary Amendment also adds new claims 13-24. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/DE99/03468 includes an International Search Report, dated March 31, 2000, and an International Preliminary Examination Report, dated March 8, 2001, copies of which are submitted herewith.

Applicant asserts that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,

KENYON & KENYON

By. [illegible] (Reg. No. 41,172)

Dated: 8/6/01

By: Richard L. Mayer

Richard L. Mayer
(Reg. No. 22,490)

One Broadway
New York, NY 10004
(212) 425-7200

09/890831
JC05 Rec'd PCT/PTO 0 6 AUG 2001

[10191/1896]

ROTARY ACTUATOR AND ROTARY SWITCH

Field Of The Invention

The present invention relates to a rotary actuator having a permanently magnetized rotor and a plurality of stator windings surrounding the rotor in a rim-like fashion, for generating magnetic fields that place the rotor in one of a first plurality of positions.

Background Information

Rotary actuators can be used as the drive for rotary switches, for example, an "R"-type waveguide switch in satellite technology.

Currently, stepping motors are generally used as actuators for purposes of this type, such as are described in European Patent No. 0 635 929. However, stepping motors have a number of characteristics that make them not seem optimally suited as actuators for rotary switches. Stepping motors are generally designed to generate a large torque that is distributed as uniformly as possible in the course of one rotation of the motor shaft, the torque making it possible to smoothly drive a mechanism that is braked using friction. This requires a minute staggering of the stator windings in the circumferential direction around the rotor, necessitating a multiplicity of terminal connections that are cumbersome to connect to wires. Figure 5a depicts an example of a rim-like arrangement of stator windings, which can place an (undepicted) rotor in four positions, each offset by 45° with respect to the others. Stator windings 1 through 4 are divided here into two diametrically opposite segments 1a, 1b,... 4a, 4b. The total of eight segments are mounted on a ring core 5, which lies in the plane of the Figure and perpendicular to rotational axis 6 of an (undepicted) rotor. Figure 5b depicts the alignments of magnetic fields B_1...B_4, which are obtained by sending current through segment pairs 1a, 1b... 4a, 4b. These vectors indicate the position in which the rotor is placed in the interior space of ring core 5. Each neighboring vector has an angular distance from adjacent vectors of 45°. By sending current through the winding segments having the opposite sign, vectors can also be generated in the opposite direction, but they generally have no practical

significance in applications of the rotary actuator for setting a rotary switch.

The large number of necessary segments makes it difficult to achieve a compact design of the actuator and renders its manufacture time-consuming and expensive.

From Japanese Laid-Open Patent Application No. 10 178 770, and the related English abstract published in Patent Abstracts of Japan, Volume 1998, No. 11, Sept. 30, 1998, a motor, in particular a stepping motor, is known which has a controllable stop position. This motor has a permanently magnetized rotor and a plurality of stator windings surrounding the rotor in a rim-like fashion, for generating magnetic fields for the purpose of placing the rotor in a plurality of positions. To place the rotor in specific positions, permanent magnets are provided between the stator windings.

Summary Of The Invention

According to the present invention, in a rotary actuator of the type cited above, elements are provided for exerting a corrective torque on the rotor, the elements, in the currentless state of the stator windings, placing the rotor in a target position from a second plurality of positions, a target position being assigned to each position of the first plurality. Therefore, whereas in conventional rotary actuators the stator windings themselves must place the rotor in a target position, in the actuator according to the present invention, this task is taken on by the elements for exerting a corrective torque. Therefore, there no longer exists the requirement that the stator windings must have an arrangement having double symmetry in order to be able to set n different positions in an angular range of 180°. Their arrangement can therefore be simpler, a high degree of symmetry in any case in the elements for exerting the corrective torque. But since the latter is smaller than the torque to be exerted by the stator windings and since the range of the latter can be significantly smaller, it is possible that the elements for exerting the corrective torque can also be significantly smaller and more compact.

In particular, these elements can be permanent magnets and therefore do not need to be wired.

Thus according to the present invention, it is possible to arrange the stator windings about the rotor in an unpaired fashion, which cuts in half the number of contacts that are needed for the power supply of the stator windings, and that must be soldered or connected in some other way. The possibility of using a number of stator windings that is smaller than the number of the first positions makes possible a further simplification of the design.

According to one preferred embodiment, the rotary actuator has four first positions and three stator windings.

Further features of the rotary actuator according to the present invention and of a rotary switch that is equipped with an actuator of this type can be derived from the description of the exemplary embodiments below.

<u>Brief Description Of The Drawings</u>

Figure 1a schematically depicts an exemplary embodiment of a rotary actuator according to the present invention having three stator windings and four first positions.

Figure 1b depicts the vectors that correspond to the magnetic fields generated only by the stator windings and to the target positions of the rotary actuator.

Figure 2 depicts a second exemplary embodiment of a rim-like arrangement of stator windings of a rotary actuator according to the present invention.

Figure 3 depicts a network having four inputs and three outputs for supplying the stator windings with current corresponding to the four first positions.

Figure 4 schematically depicts an "R"-type waveguide switch in four different switching positions.

Figure 5a depicts a conventional arrangement of stator windings; and

Figure 5b depicts the orientation of the magnetic fields generated by the stator windings in Figure 5a.

Detailed Description

Figure 1a depicts the components of a rotary actuator according to the present invention. The actuator includes three stator windings 1, 2, 3, which are arranged in a rim-like fashion, symmetrically about an axis 6 that is perpendicular to the plane of the Figure, at an angular distance in each case of 120°. The stator windings can be selectively connected to an (undepicted) power supply, the polarity of power supply terminals 8 of the stator windings being selected so that windings 1 and 3 generate a magnetic field that is equally oriented with respect to an imaginary circumferential line 9, and stator winding 2 generates a magnetic field having the opposite orientation. Thus as a result of a current being sent through stator windings 1, 2, 3, magnetic fields B_1, B_2, B_3, having the orientations depicted in Figure 1b, are obtained, which are offset by 60° with respect to each other.

A rotor 7, which for the sake of simplicity is depicted in Figure 1a as a bar magnet, can rotate freely about axis 6 under the influence of the magnetic fields generated by stator windings 1, 2, 3; in Figure 1a, it is depicted in the position which corresponds to the case in which only stator winding 1 is supplied with current.

Rotor 7 can adopt other positions corresponding to the orientation of magnetic fields B_2, B_3, if one of windings 2, 3 is supplied with current.

Four auxiliary magnets 11, 12, 13, 14 are mounted so as to be radially oriented at different locations outside the area covered by rotor 7 in its rotary motion. A first auxiliary magnet 11 is mounted in a position which shifts the orientation of magnetic field B_1 by 7.5° in the clockwise direction. Auxiliary magnet 11 has a polarity such that it exerts an attractive force on rotor 7 in the position depicted in Figure 1a adopted under the influence of magnetic field B_1. If the power supply to winding 1 is terminated, rotor 7 under the influence of auxiliary magnet 11 rotates to a target position Z_1 (see Figure 1b), in which it is directly facing auxiliary magnet 11.

A further auxiliary magnet 14 is arranged so as to be offset with respect to auxiliary magnet 11 by 45° in the clockwise direction and to have a polarity that is opposite to the latter's. Under the influence of a magnetic field generated by winding 3, rotor 7 adopts a position corresponding to vector B_3 in Figure 1b, if this magnetic field is switched off, rotor 7 under the influence of auxiliary magnet 14 rotates 7.5° to a target position, which corresponds to vector Z_4 in Figure 1b. Vectors Z_1, Z_4 constitute an angle of 135°.

Two further auxiliary magnets 12, 13 are arranged so that they can maintain rotor 7 in target positions Z_2, Z_3. Four target positions Z_1, Z_2, Z_3, Z_4 are offset by 45° with respect to each other.

Auxiliary magnets 11, 12, 13, 14 are dimensioned so that they have the capacity to pull the rotor to themselves from an angular distance of up to roughly +/-20°.

Auxiliary magnets 11, 13, on the one hand, and 12, 14, on the other hand, have different polarities with respect to the radial direction and cooperate with different poles of rotor 7. The influence of each of them can be supported by an (undepicted in Figure 1a) second auxiliary magnet situated diametrically opposite. If the rotary actuator has four target positions, as in the case described here by way of example, there are therefore eight locations at which auxiliary magnets can be arranged. However, it is sufficient if for every target position only one of these two locations is occupied. Preferably, as is depicted in Figure 1a, the one of the two locations is occupied which is left vacant by a stator winding, because this makes the more compact design possible.

As can be seen in Figure 1b, vector B_2 of the magnetic field generated by stator winding 2 lies precisely on the line bisecting the angle between two target positions Z_3 and Z_2. Therefore, it is not possible to set two target positions Z_2 or Z_3, by one of the stator windings being temporarily charged with current and rotor 7 then being left to the influence of the auxiliary magnets, which pull it into the desired target position. For this reason, three stator windings 1, 2, 3 are advantageously provided with current via a network, as depicted in Figure 3. The network has four inputs 20_1 through 20_4 and three outputs 21_1 through 21_3. Inputs 20_1 and 20_4 make it possible for a current to flow via a diode 22_1, or 22_3, to winding 1, or 3, respectively.

If one of these inputs is supplied with current, rotor 7 as a consequence adopts a first position, which corresponds to the orientation of a magnetic field B_1, or B_3. If input 20_2 is supplied with current, one part of the current flows via a diode 22_3 to winding 2 and the rest of the current flows via a diode 22_2 and a resistor 23_1 to winding 1. The magnetic fields generated by windings 1, 2 overlap each other in a field B_{21}, whose vector is depicted in Figure 1b by a dotted line. As a consequence, if input 20_2 is supplied with current, rotor 7 adopts a first position corresponding to field B_{21}, from which, if the power supply is switched off, it can reliably be pulled into target position Z_2 by corresponding auxiliary magnet 12.

If the choice of the resistance value of resistor 23_1 is suitable, the angular distance between B_{21} and Z_2 can be made as small as desired, or the two positions can be brought into agreement.

By analogy to input 20_2, input 20_3 is connected via diode 22_4 to winding 2 and via diode 22_5 and a resistor 23_3 to winding 3, so that a current that is applied to the network at input 20_3 is distributed over windings 2, 3 and results in a superimposed magnetic field B_{21}, as is depicted in Figure 1b by a dotted line.

In this manner, by one of inputs 20_1 through 20_4 of the network in Figure 3 being selectively charged with current, it is possible to place rotor 7 in one of a plurality of first positions and subsequently, under the influence of auxiliary magnets 11 through 14, to cause it to pass to a target position, which can be offset with respect to the first position by a small angle.

Optionally, a resistor 23_3 can be arranged upstream of output 21_2 that is assigned to winding 2, to make the resistance of the arrangement made up of network and windings the same for all inputs 20_1 through 20_4 of the network.

One preferred application of the rotary actuator is the drive of an "R"-type switch 25, as depicted in Figure 4 in different switching positions. This switch 25 has a frame having four input/outputs 26_1 through 26_4 and an adjusting body 27 that rotates in the frame. Adjusting body 27 is coupled to the rotor of an actuator, as is described with regard to Figure 1 and Figure 2, and can therefore be adjusted among four positions, which are depicted in parts a

through d of Figure 4.

Adjusting body 27 contains three channels 28, which in the various switching positions are connected in each case to different input/outputs 26_1... 26_4. In three of the four switching positions, any input/output, for example 26_1, is connected in each case with one of the three other outputs 26_2 through 26_4, and in a fourth switching state it is disconnected.

These "R"-type switches, especially "R"-type waveguide switches, in which the input/outputs and the channels are waveguide for high frequency signals, are used especially in space travel for the redundancy switches in payloads.

It is obvious that the rotary actuator that is described above specifically for the case of three stator windings and four target positions can also be applied for other numbers of stator windings and positions.

In addition, magnetic fields such as magnetic fields B_1, B_2 and B_3 in Figure 1b, which define the first positions of the rotor, do not necessarily have to be generated by one single stator winding. Thus, for example, in the case of Figure 2, if one of the stator windings, for example winding 2, is supplied with a current in accordance with the signs indicated at their terminals 8, it is conceivable, in order to generate field B_2, to simultaneously supply current to stator windings 1 and 3 in series with each other and parallel to winding 2, in accordance with the signs indicated at terminals 8 of windings 1 and 3, so as, in this manner, to strengthen the magnetic field in the interior space of ring core 5, to which rotor 7 is exposed.

Abstract Of The Disclosure

To simplify the design of a rotary actuator, in particular for an "R"-type waveguide switch, having a permanently magnetized rotor and a plurality of stator windings surrounding the rotor in a rim-like fashion, for generating magnetic fields which place the rotor in one of a first plurality of positions, it is proposed to furnish the actuator with elements for exerting a corrective torque on the rotor, the elements placing the rotor, in the currentless state of the stator windings, in a target position of a second plurality of positions, each position of the first plurality having assigned to it a target position.

09/890831
JC05 Rec'd PCT/PTO 06 AUG 2001

[10191/1896]

ROTARY ACTUATOR AND ROTARY SWITCH

[Background Information] Field Of The Invention

The present invention relates to a rotary actuator having a permanently magnetized rotor and a plurality of stator windings surrounding the rotor in a rim-like fashion, for generating magnetic fields that place the rotor in one of a first plurality of positions.

Background Information

Rotary actuators [of this type] can be used as the drive for rotary switches, for example, an "R"-type waveguide switch in satellite technology.

Currently, stepping motors are generally used as actuators for purposes of this type, such as are described in European Patent No. 0 635 929 [B1]. However, stepping motors have a number of characteristics that make them not seem optimally suited as actuators for rotary switches. Stepping motors are generally designed to generate a large torque that is distributed as uniformly as possible in the course of one rotation of the motor shaft, the torque making it possible to smoothly drive a mechanism that is braked using friction. This requires a minute staggering of the stator windings in the circumferential direction around the rotor, necessitating a multiplicity of terminal connections that are cumbersome to connect to wires. Figure 5a depicts an example of a rim-like arrangement of stator windings, which can place an (undepicted) rotor in four positions, each offset by 45° with respect to the others. Stator windings 1 through 4 are divided here into two diametrically opposite segments 1a, 1b,... 4a, 4b. The total of eight segments are mounted on a ring core 5, which lies in the plane of the Figure and perpendicular to rotational axis 6 of an (undepicted) rotor. Figure 5b depicts the alignments of magnetic fields B_1...B_4, which are obtained by sending current through segment pairs 1a, 1b... 4a, 4b. These vectors indicate the position in which the rotor is placed in the interior space of ring core 5. Each neighboring vector has an angular distance from adjacent vectors of 45°. By sending current through the winding segments having the opposite sign, vectors can also be generated in the opposite direction, but they generally have no practical

significance in applications of the rotary actuator for setting a rotary switch.

The large number of necessary segments makes it difficult to achieve a compact design of the actuator and renders its manufacture time-consuming and expensive.

From Japanese Laid-Open Patent Application No. 10 178 770, and the related English abstract published in Patent Abstracts of Japan, Volume 1998, No. 11, Sept. 30, 1998, a motor, in particular a stepping motor, is known which has a controllable stop position. This motor has a permanently magnetized rotor and a plurality of stator windings surrounding the rotor in a rim-like fashion, for generating magnetic fields for the purpose of placing the rotor in a plurality of positions. To place the rotor in specific positions, permanent magnets are provided between the stator windings.

Summary Of The [Advantages of the] Invention

According to the present invention, in a rotary actuator of the type cited above, [means] elements are provided for exerting a corrective torque on the rotor, the [means] elements, in the currentless state of the stator windings, placing the rotor in a target position from a second plurality of positions, a target position being assigned to each position of the first plurality. Therefore, whereas in conventional rotary actuators the stator windings themselves must place the rotor in a target position, in the actuator according to the present invention, this task is taken on by the [means] elements for exerting a corrective torque. Therefore, there no longer exists the requirement that the stator windings must have an arrangement having double symmetry in order to be able to set n different positions in an angular range of 180°. Their arrangement can therefore be simpler, a high degree of symmetry [being necessary] in any case in the [means] elements for exerting the corrective torque. But since the latter is smaller than the torque to be exerted by the stator windings and since the range of the latter can be significantly smaller, it is possible that the [means] elements for exerting the corrective torque can also be significantly smaller and more compact.

In particular, these [means] elements can be permanent magnets and therefore do not need to be wired.

Thus according to the present invention, it is possible to arrange the stator windings about the rotor in an unpaired fashion, which cuts in half the number of contacts that are needed for the power supply of the stator windings, and that must be soldered or connected in some other way. The possibility of using a number of stator windings that is smaller than the number of the first positions makes possible a further simplification of the design.

According to one preferred embodiment, the rotary actuator has four first positions and three stator windings.

Further features of the rotary actuator according to the present invention and of a rotary switch that is equipped with an actuator of this type can be derived from the description of the exemplary embodiments below.

[Figures] Brief Description Of The Drawings

Figure 1a schematically depicts an exemplary embodiment of a rotary actuator according to the present invention having three stator windings and four first positions.

Figure 1b depicts the vectors that correspond to the magnetic fields generated only by the stator windings and to the target positions of the rotary actuator.

Figure 2 depicts a second exemplary embodiment of a rim-like arrangement of stator windings of a rotary actuator according to the present invention.

Figure 3 depicts a network having four inputs and three outputs for supplying the stator windings with current corresponding to the four first positions.

Figure 4 schematically depicts an "R"-type waveguide switch in four different switching positions.

Figure 5a depicts a conventional arrangement of stator windings; and

Figure 5b depicts the orientation of the magnetic fields generated by the stator windings in Figure 5a.

Detailed Description

Figure 1a depicts the [essential] components of a rotary actuator according to the present invention. The actuator includes three stator windings 1, 2, 3, which are arranged in a rim-like fashion, symmetrically about an axis 6 that is perpendicular to the plane of the Figure, at an angular distance in each case of 120°. The stator windings can be selectively connected to an (undepicted) power supply, the polarity of power supply terminals 8 of the stator windings being selected so that windings 1 and 3 generate a magnetic field that is equally oriented with respect to an imaginary circumferential line 9, and stator winding 2 generates a magnetic field having the opposite orientation. Thus as a result of a current being sent through stator windings 1, 2, 3, magnetic fields B_1, B_2, B_3, having the orientations depicted in Figure 1b, are obtained, which are offset by 60° with respect to each other.

A rotor 7, which for the sake of simplicity is depicted in Figure 1a as a bar magnet, can rotate freely about axis 6 under the influence of the magnetic fields generated by stator windings 1, 2, 3; in Figure 1a, it is depicted in the position which corresponds to the case in which only stator winding 1 is supplied with current.

Rotor 7 can adopt other positions corresponding to the orientation of magnetic fields B_2, B_3, if one of windings 2, 3 is supplied with current.

Four auxiliary magnets 11, 12, 13, 14 are mounted so as to be radially oriented at different locations outside the area covered by rotor 7 in its rotary motion. A first auxiliary magnet 11 is mounted in a position which shifts the orientation of magnetic field B_1 by 7.5° in the clockwise direction. Auxiliary magnet 11 has a polarity such that it exerts an attractive force on rotor 7 in the position depicted in Figure 1a adopted under the influence of magnetic field B_1. If the power supply to winding 1 is terminated, rotor 7 under the influence of auxiliary magnet 11 rotates to a target position Z_1 (see Figure 1b), in which it is directly facing auxiliary magnet 11.

A further auxiliary magnet 14 is arranged so as to be offset with respect to auxiliary magnet 11 by 45° in the clockwise direction and to have a polarity that is opposite to the latter's. Under the influence of a magnetic field generated by winding 3, rotor 7 adopts a position corresponding to vector B_3 in Figure 1b, if this magnetic field is switched off, rotor 7 under the influence of auxiliary magnet 14 rotates 7.5° to a target position, which corresponds to vector Z_4 in Figure 1b. Vectors Z_1, Z_4 constitute an angle of 135°.

Two further auxiliary magnets 12, 13 are arranged so that they can maintain rotor 7 in target positions Z_2, Z_3. Four target positions Z_1, Z_2, Z_3, Z_4 are offset by 45° with respect to each other.

Auxiliary magnets 11, 12, 13, 14 are dimensioned so that they have the capacity to pull the rotor to themselves from an angular distance of up to roughly +/-20°.

Auxiliary magnets 11, 13, on the one hand, and 12, 14, on the other hand, have different polarities with respect to the radial direction and cooperate with different poles of rotor 7. The influence of each of them can be supported by an (undepicted in Figure 1a) second auxiliary magnet situated diametrically opposite. If the rotary actuator has four target positions, as in the case described here by way of example, there are therefore eight locations at which auxiliary magnets can be arranged. However, it is sufficient if for every target position only one of these two locations is occupied. Preferably, as is depicted in Figure 1a, the one of the two locations is occupied which is left vacant by a stator winding, because this makes the more compact design possible.

As can be seen in Figure 1b, vector B_2 of the magnetic field generated by stator winding 2 lies precisely on the line bisecting the angle between two target positions Z_3 and Z_2. Therefore, it is not possible to set two target positions Z_2 or Z_3, by one of the stator windings being temporarily charged with current and rotor 7 then being left to the influence of the auxiliary magnets, which pull it into the desired target position. For this reason, three stator windings 1, 2, 3 are advantageously provided with current via a network, as depicted in Figure 3. The network has four inputs 20_1 through 20_4 and three outputs 21_1 through 21_3. Inputs 20_1 and 20_4 make it possible for a current to flow via a diode 22_1, or 22_3, to winding 1, or 3, respectively.

If one of these inputs is supplied with current, rotor 7 as a consequence adopts a first position, which corresponds to the orientation of a magnetic field B_1, or B_3. If input 20_2 is supplied with current, one part of the current flows via a diode 22_3 to winding 2 and the rest of the current flows via a diode 22_2 and a resistor 23_1 to winding 1. The magnetic fields generated by windings 1, 2 overlap each other in a field B_{21}, whose vector is depicted in Figure 1b by a dotted line. As a consequence, if input 20_2 is supplied with current, rotor 7 adopts a first position corresponding to field B_{21}, from which, if the power supply is switched off, it can reliably be pulled into target position Z_2 by corresponding auxiliary magnet 12.

If the choice of the resistance value of resistor 23_1 is suitable, the angular distance between B_{21} and Z_2 can be made as small as desired, or the two positions can be brought into agreement.

By analogy to input 20_2, input 20_3 is connected via diode 22_4 to winding 2 and via diode 22_5 and a resistor 23_3 to winding 3, so that a current that is applied to the network at input 20_3 is distributed over windings 2, 3 and results in a superimposed magnetic field B_{21}, as is depicted in Figure 1b by a dotted line.

In this manner, by one of inputs 20_1 through 20_4 of the network in Figure 3 being selectively charged with current, it is possible to place rotor 7 in one of a plurality of first positions and subsequently, under the influence of auxiliary magnets 11 through 14, to cause it to pass to a target position, which can be offset with respect to the first position by a small angle.

Optionally, a resistor 23_3 can be arranged upstream of output 21_2 that is assigned to winding 2, to make the resistance of the arrangement made up of network and windings the same for all inputs 20_1 through 20_4 of the network.

One preferred application of the rotary actuator is the drive of an "R"-type switch 25, as depicted in Figure 4 in different switching positions. This switch 25 has a frame having four input/outputs 26_1 through 26_4 and an adjusting body 27 that rotates in the frame. Adjusting body 27 is coupled to the rotor of an actuator, as is described with regard to Figure 1 and Figure 2, and can therefore be adjusted among four positions, which are depicted in parts a

through d of Figure 4.

Adjusting body 27 contains three channels 28, which in the various switching positions are connected in each case to different input/outputs $26_1 ... 26_4$. In three of the four switching positions, any input/output, for example 26_1, is connected in each case with one of the three other outputs 26_2 through 26_4, and in a fourth switching state it is disconnected.

These "R"-type switches, especially "R"-type waveguide switches, in which the input/outputs and the channels are waveguide for high frequency signals, are used especially in space travel for the redundancy switches in payloads.

It is obvious that the rotary actuator that is described above specifically for the case of three stator windings and four target positions can also be applied for other numbers of stator windings and positions.

In addition, magnetic fields such as magnetic fields B_1, B_2 and B_3 in Figure 1b, which define the first positions of the rotor, do not necessarily have to be generated by one single stator winding. Thus, for example, in the case of Figure 2, if one of the stator windings, for example winding 2, is supplied with a current in accordance with the signs indicated at their terminals 8, it is conceivable, in order to generate field B_2, to simultaneously supply current to stator windings 1 and 3 in series with each other and parallel to winding 2, in accordance with the signs indicated at terminals 8 of windings 1 and 3, so as, in this manner, to strengthen the magnetic field in the interior space of ring core 5, to which rotor 7 is exposed.

Abstract Of The Disclosure

To simplify the design of a rotary actuator, in particular for an "R"-type waveguide switch, having a permanently magnetized rotor [(7)] and a plurality of stator windings [(1, 2, 3)] surrounding the rotor in a rim-like fashion, for generating magnetic fields which place the rotor in one of a first plurality of positions, it is proposed to furnish the actuator with [means (11, 12, 13, 14)] elements for exerting a corrective torque on the rotor, the [means] elements placing the rotor[(7)], in the currentless state of the stator windings[(1, 2, 3)], in a target position of a second plurality of positions, each position of the first plurality having assigned to it a target position.

[Figure 1a]

[10191/1896]

ROTARY ACTUATOR AND ROTARY SWITCH

Background Information

The present invention relates to a rotary actuator having a permanently magnetized rotor and a plurality of stator windings surrounding the rotor in a rim-like fashion, for generating magnetic fields that place the rotor in one of a first plurality of positions.

Rotary actuators of this type can be used as the drive for rotary switches, for example, an "R"-type waveguide switch in satellite technology.

Currently, stepping motors are generally used as actuators for purposes of this type, such as are described in European Patent 0 635 929 B1. However, stepping motors have a number of characteristics that make them not seem optimally suited as actuators for rotary switches. Stepping motors are generally designed to generate a large torque that is distributed as uniformly as possible in the course of one rotation of the motor shaft, the torque making it possible to smoothly drive a mechanism that is braked using friction. This requires a minute staggering of the stator windings in the circumferential direction around the rotor, necessitating a multiplicity of terminal connections that are cumbersome to connect to wires. Figure 5a depicts an example of a rim-like arrangement of stator windings, which can place an (undepicted) rotor in four positions, each offset by 45° with respect to the others. Stator windings 1 through 4 are divided here into two diametrically opposite segments 1a, 1b,... 4a, 4b. The total of eight segments are mounted on a ring core 5, which lies in the plane of the Figure and perpendicular to rotational axis 6 of an (undepicted) rotor. Figure 5b depicts the alignments of magnetic fields $B_1 \ldots B_4$, which are obtained by sending current through segment pairs 1a, 1b... 4a, 4b. These vectors indicate the position in which the rotor is placed in the interior space of ring core 5. Each neighboring vector has an angular distance from adjacent vectors of 45°. By sending current through the winding segments having the opposite sign, vectors can also be generated in the opposite direction, but they generally have no practical significance in applications of the rotary actuator for setting a rotary switch.

The large number of necessary segments makes it difficult to achieve a compact design of the actuator and renders its manufacture time-consuming and expensive.

Advantages of the Invention

According to the present invention, in a rotary actuator of the type cited above, means are provided for exerting a corrective torque on the rotor, the means, in the currentless state of the stator windings, placing the rotor in a target position from a second plurality of positions, a target position being assigned to each position of the first plurality. Therefore, whereas in conventional rotary actuators the stator windings themselves must place the rotor in a target position, in the actuator according to the present invention, this task is taken on by the means for exerting a corrective torque. Therefore, there no longer exists the requirement that the stator windings must have an arrangement having double symmetry in order to be able to set n different positions in an angular range of 180°. Their arrangement can therefore be simpler, a high degree of symmetry being necessary in any case in the means for exerting the corrective torque. But since the latter is smaller than the torque to be exerted by the stator windings and since the range of the latter can be significantly smaller, it is possible that the means for exerting the corrective torque can also be significantly smaller and more compact.

In particular, these means can be permanent magnets and therefore do not need to be wired.

Thus according to the present invention, it is possible to arrange the stator windings about the rotor in an unpaired fashion, which cuts in half the number of contacts that are needed for the power supply of the stator windings, and that must be soldered or connected in some other way. The possibility of using a number of stator windings that is smaller than the number of the first positions makes possible a further simplification of the design.

According to one preferred embodiment, the rotary actuator has four first positions and three stator windings.

Further features of the rotary actuator according to the present invention and of a rotary switch that is equipped with an actuator of this type can be derived from the description of the exemplary embodiments below.

Figures

Figure 1a schematically depicts an exemplary embodiment of a rotary actuator according to the present invention having three stator windings and four first positions.

Figure 1b depicts the vectors that correspond to the magnetic fields generated only by the stator windings and to the target positions of the rotary actuator.

Figure 2 depicts a second exemplary embodiment of a rim-like arrangement of stator windings of a rotary actuator according to the present invention.

Figure 3 depicts a network having four inputs and three outputs for supplying the stator windings with current corresponding to the four first positions.

Figure 4 schematically depicts an "R"-type waveguide switch in four different switching positions.

Figure 5a depicts a conventional arrangement of stator windings; and

Figure 5b depicts the orientation of the magnetic fields generated by the stator windings in Figure 5a.

Figure 1a depicts the essential components of a rotary actuator according to the present invention. The actuator includes three stator windings 1, 2, 3, which are arranged in a rim-like fashion, symmetrically about an axis 6 that is perpendicular to the plane of the Figure, at an angular distance in each case of 120°. The stator windings can be selectively connected to an (undepicted) power supply, the polarity of power supply terminals 8 of the stator windings being selected so that windings 1 and 3 generate a magnetic field that is equally oriented with respect to an imaginary circumferential line 9, and stator winding 2 generates a magnetic field having the opposite orientation. Thus as a result of a current being sent through stator windings 1, 2, 3, magnetic fields B_1, B_2, B_3, having the orientations depicted in Figure 1b, are obtained, which are offset by 60° with respect to each other.

A rotor 7, which for the sake of simplicity is depicted in Figure 1a as a bar magnet, can rotate freely about axis 6 under the influence of the magnetic fields generated by stator windings 1, 2, 3; in Figure 1a, it is depicted in the position which corresponds to the case in which only stator winding 1 is supplied with current.

Rotor 7 can adopt other positions corresponding to the orientation of magnetic fields B_2, B_3, if one of windings 2, 3 is supplied with current.

Four auxiliary magnets 11, 12, 13, 14 are mounted so as to be radially oriented at different locations outside the area covered by rotor 7 in its rotary motion. A first auxiliary magnet 11 is mounted in a position which shifts the orientation of magnetic field B_1 by 7.5° in the clockwise direction. Auxiliary magnet 11 has a polarity such that it exerts an attractive force on rotor 7 in the position depicted in Figure 1a adopted under the influence of magnetic field B_1. If the power supply to winding 1 is terminated, rotor 7 under the influence of auxiliary magnet 11 rotates to a target position Z_1 (see Figure 1b), in which it is directly facing auxiliary magnet 11.

A further auxiliary magnet 14 is arranged so as to be offset with respect to auxiliary magnet 11 by 45° in the clockwise direction and to have a polarity that is opposite to the latter's. Under the influence of a magnetic field generated by winding 3, rotor 7 adopts a position corresponding to vector B_3 in Figure 1b, if this magnetic field is switched off, rotor 7 under the influence of auxiliary magnet 14 rotates 7.5° to a target position, which corresponds to vector Z_4 in Figure 1b. Vectors Z_1, Z_4 constitute an angle of 135°.

Two further auxiliary magnets 12, 13 are arranged so that they can maintain rotor 7 in target positions Z_2, Z_3. Four target positions Z_1, Z_2, Z_3, Z_4 are offset by 45° with respect to each other.

Auxiliary magnets 11, 12, 13, 14 are dimensioned so that they have the capacity to pull the rotor to themselves from an angular distance of up to roughly +/-20°.

Auxiliary magnets 11, 13, on the one hand, and 12, 14, on the other hand, have different polarities with respect to the radial direction and cooperate with different poles of rotor 7. The

influence of each of them can be supported by an (undepicted in Figure 1a) second auxiliary magnet situated diametrically opposite. If the rotary actuator has four target positions, as in the case described here by way of example, there are therefore eight locations at which auxiliary magnets can be arranged. However, it is sufficient if for every target position only one of these two locations is occupied. Preferably, as is depicted in Figure 1a, the one of the two locations is occupied which is left vacant by a stator winding, because this makes the more compact design possible.

As can be seen in Figure 1b, vector B_2 of the magnetic field generated by stator winding 2 lies precisely on the line bisecting the angle between two target positions Z_3 and Z_2. Therefore, it is not possible to set two target positions Z_2 or Z_3, by one of the stator windings being temporarily charged with current and rotor 7 then being left to the influence of the auxiliary magnets, which pull it into the desired target position. For this reason, three stator windings 1, 2, 3 are advantageously provided with current via a network, as depicted in Figure 3. The network has four inputs 20_1 through 20_4 and three outputs 21_1 through 21_3. Inputs 20_1 and 20_4 make it possible for a current to flow via a diode 22_1, or 22_3, to winding 1, or 3, respectively. If one of these inputs is supplied with current, rotor 7 as a consequence adopts a first position, which corresponds to the orientation of a magnetic field B_1, or B_3. If input 20_2 is supplied with current, one part of the current flows via a diode 22_3 to winding 2 and the rest of the current flows via a diode 22_2 and a resistor 23_1 to winding 1. The magnetic fields generated by windings 1, 2 overlap each other in a field B_{21}, whose vector is depicted in Figure 1b by a dotted line. As a consequence, if input 20_2 is supplied with current, rotor 7 adopts a first position corresponding to field B_{21}, from which, if the power supply is switched off, it can reliably be pulled into target position Z_2 by corresponding auxiliary magnet 12.

If the choice of the resistance value of resistor 23_1 is suitable, the angular distance between B_{21} and Z_2 can be made as small as desired, or the two positions can be brought into agreement.

By analogy to input 20_2, input 20_3 is connected via diode 22_4 to winding 2 and via diode 22_5 and a resistor 23_3 to winding 3, so that a current that is applied to the network at input 20_3 is distributed over windings 2, 3 and results in a superimposed magnetic field B_{21}, as is depicted in Figure 1b by a dotted line.

In this manner, by one of inputs 20_1 through 20_4 of the network in Figure 3 being selectively charged with current, it is possible to place rotor 7 in one of a plurality of first positions and subsequently, under the influence of auxiliary magnets 11 through 14, to cause it to pass to a target position, which can be offset with respect to the first position by a small angle.

Optionally, a resistor 23_3 can be arranged upstream of output 21_2 that is assigned to winding 2, to make the resistance of the arrangement made up of network and windings the same for all inputs 20_1 through 20_4 of the network.

One preferred application of the rotary actuator is the drive of an "R"-type switch 25, as depicted in Figure 4 in different switching positions. This switch 25 has a frame having four input/outputs 26_1 through 26_4 and an adjusting body 27 that rotates in the frame. Adjusting body 27 is coupled to the rotor of an actuator, as is described with regard to Figure 1 and Figure 2, and can therefore be adjusted among four positions, which are depicted in parts a through d of Figure 4.

Adjusting body 27 contains three channels 28, which in the various switching positions are connected in each case to different input/outputs 26_1... 26_4. In three of the four switching positions, any input/output, for example 26_1, is connected in each case with one of the three other outputs 26_2 through 26_4, and in a fourth switching state it is disconnected.

These "R"-type switches, especially "R"-type waveguide switches, in which the input/outputs and the channels are waveguide for high frequency signals, are used especially in space travel for the redundancy switches in payloads.

It is obvious that the rotary actuator that is described above specifically for the case of three stator windings and four target positions can also be applied for other numbers of stator windings and positions.

In addition, magnetic fields such as magnetic fields B_1, B_2 and B_3 in Figure 1b, which define the first positions of the rotor, do not necessarily have to be generated by one single stator winding. Thus, for example, in the case of Figure 2, if one of the stator windings, for example winding 2, is supplied with a current in accordance with the signs indicated at their terminals

8, it is conceivable, in order to generate field B_2, to simultaneously supply current to stator windings 1 and 3 in series with each other and parallel to winding 2, in accordance with the signs indicated at terminals 8 of windings 1 and 3, so as, in this manner, to strengthen the magnetic field in the interior space of ring core 5, to which rotor 7 is exposed.

What is claimed is:

1. The rotary actuator having a permanently magnetized rotor (7) and a plurality of stator windings (1, 2, 3) surrounding the rotor (7) in a rim-like fashion for generating magnetic fields (B_1, B_{21}, B_{23}, B_3), which place the rotor (7) in one of a first plurality of positions, wherein it has available to it means (11, 12, 13, 14) for exerting a corrective torque on the rotor (7), the means, in the currentless state of the stator windings (1, 2, 3), placing the rotor in a target position of a second plurality of positions (Z_1, Z_2, Z_3), each position of the first plurality having assigned to it a target position.

2. The rotary actuator as recited in Claim 1,
wherein the rotor (7) includes a magnet that is aligned so as to be perpendicular to the rotational axis (6).

3. The rotary actuator as recited in Claim 1 or 2,
wherein the stator windings (1, 2, 3) are arranged so as to be unpaired.

4. The rotary actuator as recited in one of the preceding claims,
wherein the stator windings (1, 2, 3) are uniformly distributed around the axis (6) in the circumferential direction.

5. The rotary actuator as recited in one of the preceding claims,
wherein the stator windings (1, 2, 3) are arranged on a ring core (5) that surrounds the rotor (7).

6. The rotary actuator as recited in one of the preceding claims,
wherein the number of stator windings (1, 2, 3) is smaller than the number of first positions.

7. The rotary actuator as recited in one of the preceding claims,
wherein the means for exerting a corrective torque (11, 12, 13, 14) are permanent magnets.

8. The rotary actuator as recited in one of the preceding claims,
characterized by a network having n inputs (20_1,... 20_4) and m outputs (21_1, 21_2, 21_3), n being the number of the first positions and m being the number of stator windings (1, 2, 3) and each stator winding (1, 2, 3) being connected to one output (21_1, 21_2, 21_3), the network distributing to the stator windings (1, 2, 3) a current applied at one of inputs (20_1,... 20_4), in order to set a first position that is assigned to the respective input.

9. The rotary actuator as recited in Claim 8,
wherein the resistance of all n inputs (20_1, ... 20_4) is the same.

10. The rotary actuator as recited in one of preceding claims,
wherein it has three stator windings (1, 2, 3) and four first positions.

11. The rotary actuator as recited in Claim 10,
wherein adjoining target positions (Z_1,... Z_4) have an angular distance of 45°.

12. A rotary switch, characterized by a rotary actuator in accordance with one of the preceding claims.

13. The rotary switch as recited in Claim 12,
wherein it is an "R"-type waveguide switch.

Abstract

To simplify the design of a rotary actuator, in particular for an "R"-type waveguide switch, having a permanently magnetized rotor (7) and a plurality of stator windings (1, 2, 3) surrounding the rotor in a rim-like fashion, for generating magnetic fields which place the rotor in one of a first plurality of positions, it is proposed to furnish the actuator with means (11, 12, 13, 14) for exerting a corrective torque on the rotor, the means placing the rotor (7), in the currentless state of the stator windings (1, 2, 3), in a target position of a second plurality of positions, each position of the first plurality having assigned to it a target position.

Figure 1a

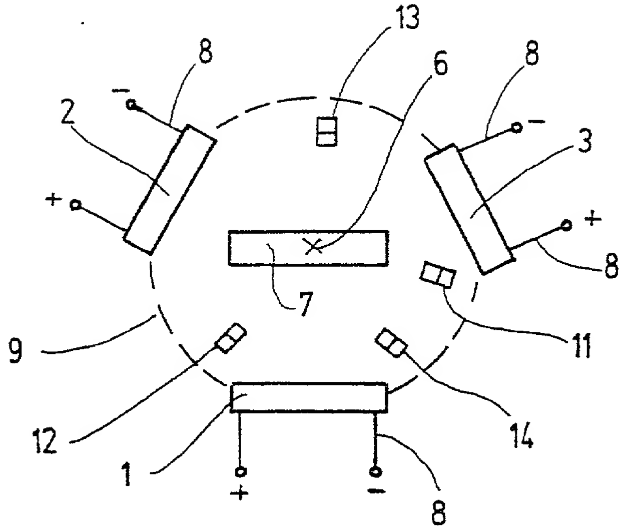


Fig. 1a

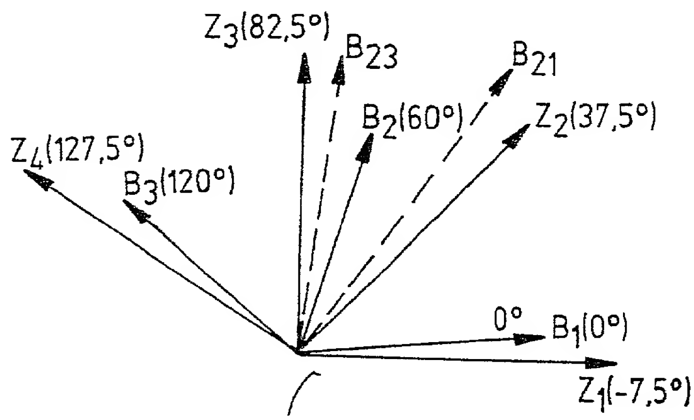


Fig. 1b

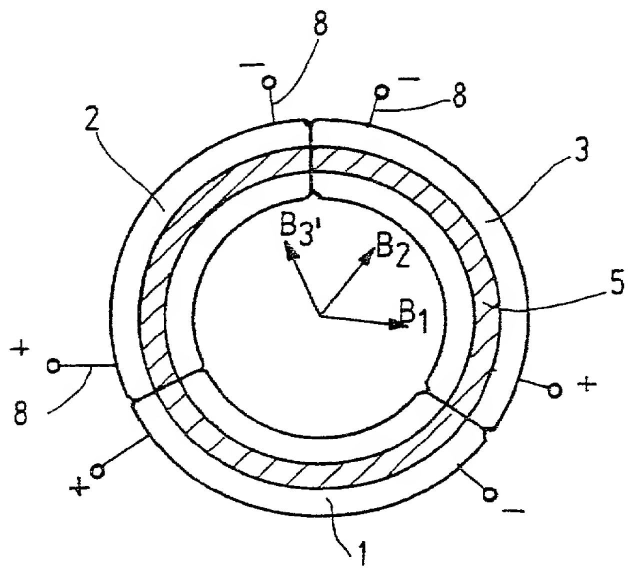
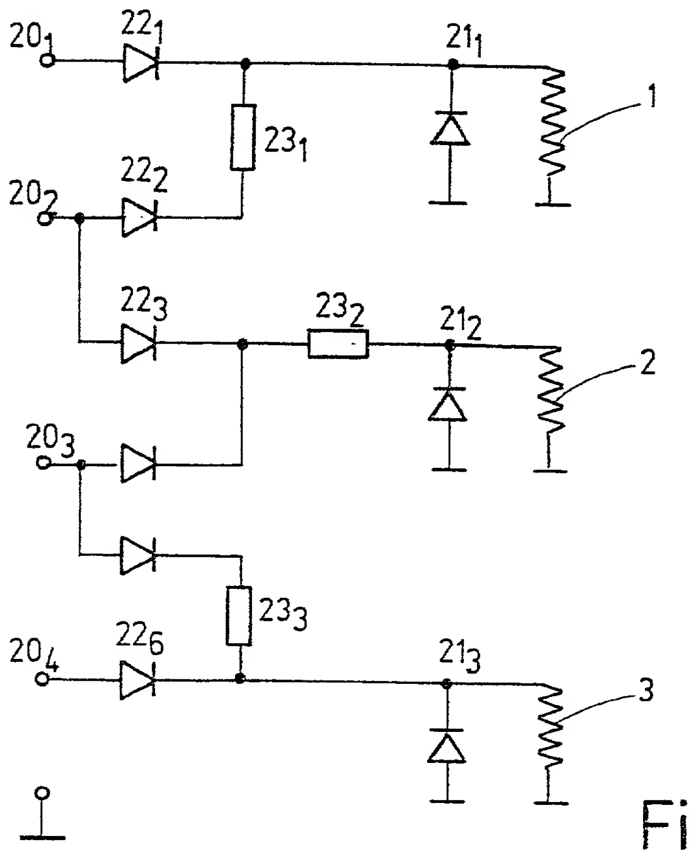
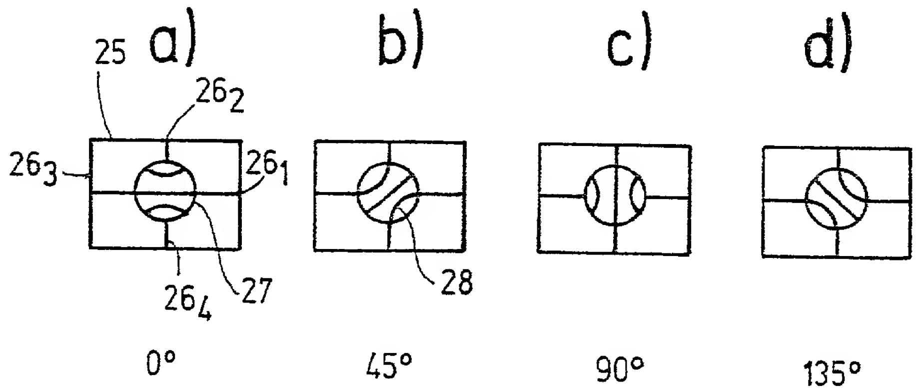


Fig. 2



20_1
22_1
21_1
1
23_1
20_2
22_2
22_3
23_2
21_2
2
20_3
23_3
20_4
22_6
21_3
3

Fig. 3



a)
b)
c)
d)
25
26_2
26_3
26_1
26_4
27
28
0°
45°
90°
135°

Fig. 4

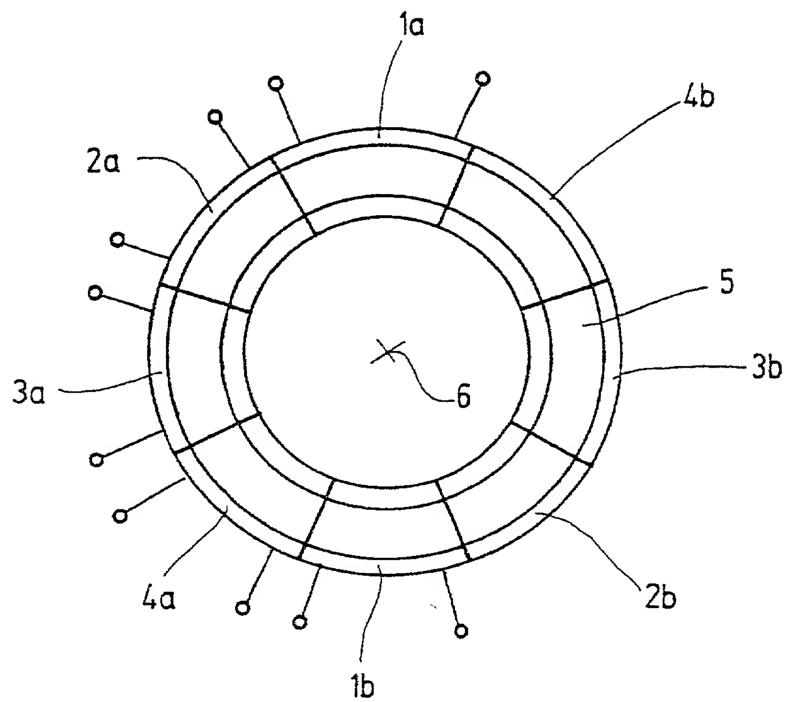


Fig. 5a

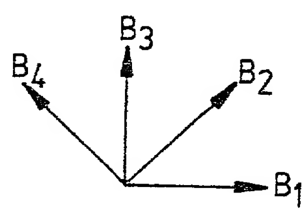


Fig. 5b

#4

COMBINED DECLARATION AND
POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below adjacent to my name.

I believe I am the original, first and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **ROTARY ACTUATOR AND ROTARY SWITCH**, and the specification of which:

[ ] is attached hereto;

[ ] was filed as United States Application Serial No. _________ on _________, 19__ and was amended by the Preliminary Amendment filed on ____________, 19__.

[X] was filed as PCT International Application Number PCT/DE99/03468 on the 30th day of October, 1999.

[X] an English translation of which is filed herewith.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a). I hereby claim foreign priority benefits under Title 35, United States Code § 119 of any foreign application(s) for patent or inventor's certificate or of any PCT international applications(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

~~EL244504400~~
EL244509818US

PRIOR FOREIGN/PCT APPLICATION(S)
<u>AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. § 119</u>

Country : Federal Republic of Germany

Application No. : 199 04 469.4

Date of Filing: February 4, 1999

Priority Claimed
Under 35 U.S.C. § 119 : [X] Yes [ ] No

I hereby claim the benefit under Title 35, United States Code § 120 of any United States Application or PCT International Application designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations § 1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

PRIOR U.S. APPLICATIONS OR
PCT INTERNATIONAL APPLICATIONS
DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. § 120

<u>U.S. APPLICATIONS</u>

Number :

Filing Date :

PCT APPLICATIONS
<u>DESIGNATING THE U.S.</u>

PCT Number :

PCT Filing Date :

I hereby appoint the following attorney(s) and/or agents to prosecute the above-identified application and transact all business in the Patent and Trademark Office connected therewith.

(List name(s) and registration number(s)):

Richard L. Mayer,	Reg. No. 22,490
Gerard A. Messina,	Reg. No. 35,952
______________,	Reg. No. ______
______________,	Reg. No. ______

All correspondence should be sent to:

Richard L. Mayer, Esq.
Kenyon & Kenyon
One Broadway
New York, New York 10004

Telephone No.: (212) 425-7200
Facsimile No.: (212) 425-5288 **CUSTOMER NO. 26646**

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

I-00

Full name of inventor: **Eckart HETTLAGE**

Inventor's signature Eckart Hettlage Date 27.09.2001

Citizenship Federal Republic of Germany

Residence Obere Setz 1
D-76229 Karlsruhe DEX
Federal Republic of Germany

Post Office Address Same as above